ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 3, March 2012

Heart Blogger System

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Abstract—***Wireless, low-cost, portable, emergency monitoring ECG device is designed in this paper. This device will provide the information about the state of heart of the patient to the concerned cardiologist through e-mail along with the required details of patient and concluded parameters like heart rate, intervals, amplitude, etc. It will help the doctors to understand the situation of patient from the distance and take the required action, if found in critical condition. Heart Blogger System is a telemetry device which is a combination of Electro-cardiograph and signal processing. The device will detect the abnormal heart rhythms and will intimate doctors to get alert for the upcoming danger to the patient's life, thus reducing the heart attack onset time considerably. The proposed device will be analyzing ECG signals of the patient in real time which is a certain advantage along with the cost effectiveness over conventional ones. Thus it will be going to play a crucial role in reducing the number of heart attack death tolls to a very low figure.***

Index Terms—**Cardiology, Emergency Device, Pulse Rate Indicator, Wireless ECG.**

I. Introduction

India through the years has been fighting with the disorders related to heart- more prominent in aged persons- which is eating away the people of India to much extent. Electrocardiogram (ECG) [1] is found to be very useful device while dealing with any kind of heart ailment. Not only in India, Coronary heart diseases are at the top of the world death cause list and every year 7.2 million people die because of these diseases. Around 60% of the heart patients in India reach hospital after the Golden Hour (a period of 60 minutes from the inception of heart attack, after which the doctor cannot do much. According to World Health Report 2002 [14], cardiovascular diseases (CVDs) will be the largest cause of death and disability by 2020 in India. It says that by 2020 AD, 2.6 million Indians are predicted to die due to coronary heart disease which constitutes 54.1 % of all CVD deaths.

Healthcare providers are planning to develop intelligent and low-cost ubiquitous systems to make life more comfortable for people suffering from heart disorders. The reason behind the deaths from heart attack is the large amount of time taken in responding to the patients. If doctor can be made aware about the state of patient in advance, then the survival rate of the patient can be increased considerably.

HBS employs use of three electrodes [8] (a certain advantage over the use of 12 electrodes [31] in terms of cost). The electrodes read the ECG signals from three crucial areas over the human body where the signals are found to be more prominent which are Right Arm, Left Arm and Right Leg, thus satisfying Einthoven's Triangle. The device also displays the pulse rate of the patient, by the help of which the patient can judge himself. We have also used the fact that disposable electrodes are far more advantageous than the conventional electrodes in terms of low signal-to-noise ratio, faster response, and even in some cases infection. Because of the advances in wireless communication and embedded computation technologies, remote health monitoring and telemedicine topics have become a very active research area recently.

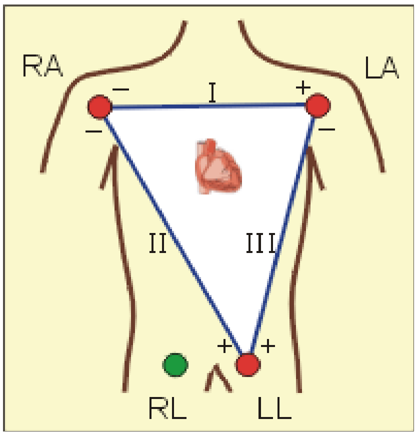

Fig. 1: Einthoven's Triangle [22]

Therefore, developing low-cost, portable and emergency device which can work outside the hospital anywhere irrespective of surrounding can be proved very valuable for the patient.

II. Background

A lot of research is being done in this field and some more are in progress, but no such device is yet commercially developed. Several researches have developed applications to monitor the ECG in mobile devices, where the samples have been obtained and then compared from standard data bases, but the results are not favourable. In our work we describe the implementation of the acquisition module with wireless [6] transmission capabilities through e-mail.

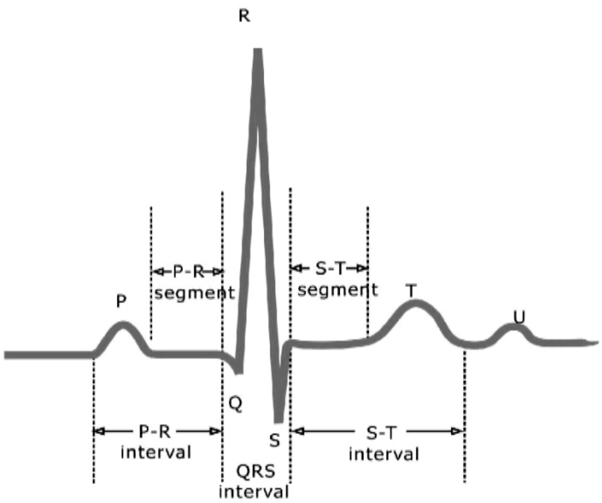

Fig. 2: ECG waveform showing different intervals [20]

The electrocardiogram, or ECG [7], is a surface measurement of the electrical potential generated by electrical activity in cardiac tissue [32]. The study of this electrical signal can be proved very helpful in determining many abnormalities related to the heart's function.

By studying the time between different points P, Q, R, S, T and U [19] [26] and the variations in these times between successive beats, many heart disorders can be detected [29].

- The P wave represents trial activation.
- The PR interval is the time from onset of trial activation to onset of ventricular activation.
- The QRS complex represents ventricular activation; the QRS duration is the duration of ventricular activation.
- The T wave represents ventricular repolarisation.
- The QT [4] interval is the duration of ventricular activation and recovery.
- The U wave probably represents "after depolarisations" in the ventricles.

Heart rate is traditionally estimated as the number of R-wave events (heartbeats) per unit time on the electrocardiogram (ECG) or as the average of the R-R interval reciprocals within a specified time window. Several approaches are used to characterize heart rate variability: elementary statistical measures of R-R interval properties, spectral analysis of heart rate or R-R interval time series, deterministic dynamical systems assessments of heart rate signal properties, and approximate entropy measures of R-R interval regularity [24].

Heart attack comes in two basic varieties [15]. The most common heart attack is caused by blood clots that block one or more of coronary arteries. These blood clots restrict the flow of blood to heart muscle, cutting off the supply of oxygen and nutrients. This condition is known as myocardial infarction. The second major type of heart attack occurs when SA node loses control of the heart muscle and causes a condition known as fibrillation. The lack of coordination can stop beating of heart and causes cardiac arrest. The normal heart beat is considered to be 60-80 beats per minute and the average heartbeat rate is 72 beats per minute [25]. With any sort of irregularity heart beat can deviate from these figures considerably, causing Arrhythmias. In even worse conditions, it can prove to be fatal. These arrhythmias can be easily seen in the ECG. Cardiac events can occur anywhere and not necessarily at doctor's place. By doing ECG irrespective of place, the condition can be captured and accordingly the required action can be taken. This ECG is analyzed by doctors having vast experience and thus is not so easy to work on. The device can analyze the ECG by interfacing it with the PC or Laptop.

Heart rate has an important relationship with the coronary artery disease or cardiovascular disease [18]: it is linearly related to the changing demand of oxygen before or after the attack. Thus, by observing the heart rate of an individual the state of heart can also be predicted. As the normal person doesn't have the detailed knowledge of the ECG, so by displaying the heart rate, they can judge the status of heart.

III. SYSTEM IMPLEMENTATION

We have developed a portable medical data acquisition system that includes heart rate and ECG. This system allows the physicians and cardiologists able to understand patient's scenario on the computer screen through e-mail. The system implementation section comprises of sensors, ECG amplifier section and the QRS detector [16] section. The electrodes pick the signal from the surface of the body. These signals are converted to the electrical signals and fed to the ECG amplifier. The amplified signals are prone to noise, so are filtered and amplified with very high gain, to make the low amplitude signals able for use. The now obtained signals are used to generate ECG wave on the software. In order to detect pulse of the patient, the QRS detector is used. It measures the interval in between Q-R-S, and thus displays the pulse rate or heart rate.

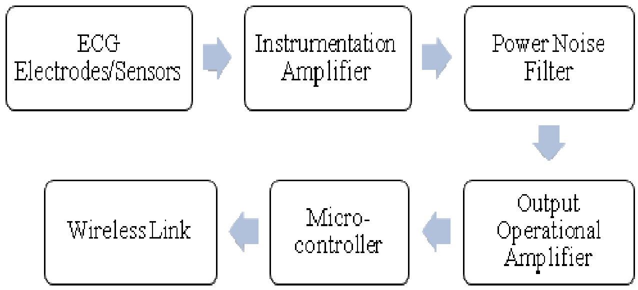

Fig. 3: Block Diagram of Heart Blogger System

A. Sensors

HBS includes use of three electrodes. The acquired signal represents the first Einthoven bipolar lead. By convention, lead I have the positive electrode on the left arm (LA), and the negative electrode on the right arm (RA), and therefore measure the potential difference through differential amplifier between the two arms. In this and the other two limb leads, an electrode on the right leg (RL) serves as a reference electrode for recording purposes. The disposable electrodes are used here which provide better signals from the human body with low noise. These electrodes are cheap, easily available and free from any type of infection as they are of single use only. Many wearable electrodes [3] are also available in the market for the same purpose.

B. ECG Amplifier

Biomedical parameters [13] are difficult to measure due to their relatively low energies (R wave usually is less than 2mv) and similarity of signals from organ to organ. This similarity makes discrimination of a particular signal difficult. Monitors require several volts of signal to operate, therefore an amplifier is necessary to boost the size of the biological signal 1000s times before its display. The input signals are obtained from the left and right arms of the patient.

The common-mode voltage is set by two input resistors. This potential through a buffer provides optional right leg drive. Filtering can be modified to suit application needs by changing the capacitor value of the output filter. An ECG

ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
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signal is usually in the range of 1 mV in magnitude and has frequency components from about 0.05–100 Hz. To process this signal, it has to be amplified. Figure 5 shows the circuit of an ECG amplifier. The typical characteristics of an ECG amplifier are high gain (about 1000), 0.05–100 Hz frequency response, high input impedance, and low output impedance.ECG signals [5] are received from human body as a result of electrical activity of heart. The amplitude of the signal varies between 0.05 mV - 10 mV and must be amplified with an amplifier. The amplified signals are generally found to contain some noise, caused by the 50 Hz interference of the power electricity lines, human body, active and passive circuit components and wires that flow current of the circuit which is suppressed by passive low pass and high pass RC filters. Low-pass filter is implemented cascaded the signals from the gain amplifier with frequency higher than 100Hz. A notch filter or band reject filter is used to reduce 60 Hz noise. Finally, a high-pass filter is used to allow the signal that has frequency above 10Hz.

The digital section comprises the data conversion section and the control unit which employs A/D converter. The control unit governs the sampling frequency, and it can be switched between (200-400) samples per second. The control unit also implements the bi-directional communication protocol to the PC, through a proper RS-232 interface provided in the HSB. The control unit is built around the Microchip PIC 16F876 with a 10-MHz clock Microcontroller. It does allow a sampling frequency of 200 samples per second although, in the current version, the patient has to stay close to the PC during the monitoring period.

Fig. 4: LM324 IC [21]

The LM324 series consists of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage [21].

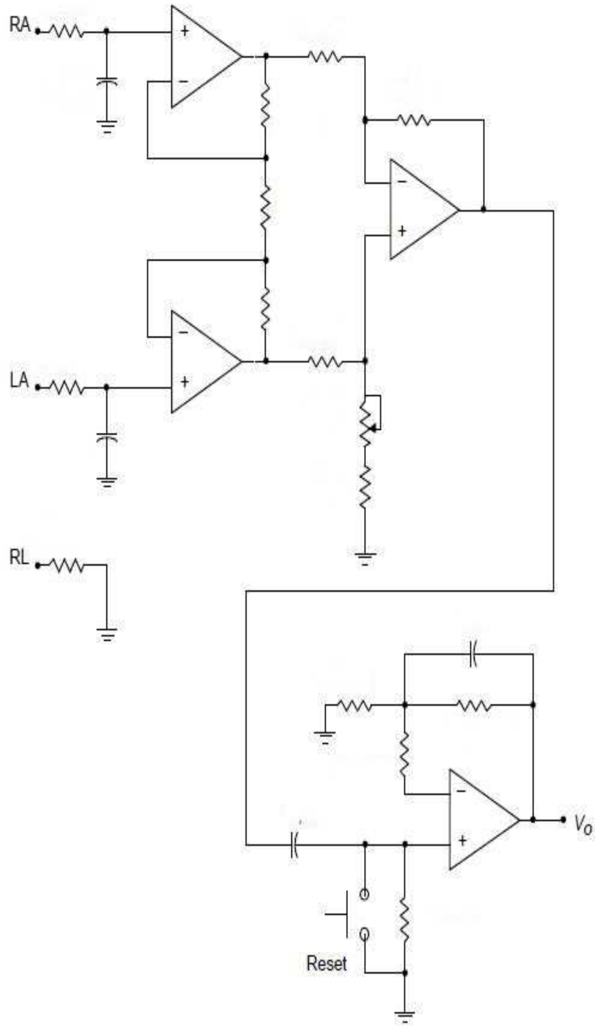

Fig.5 Circuit diagram of ECG Amplifier

C. QRS Detector

The detection of the QRS complexes in an ECG signal provides information about the heart rate, the conduction velocity, the condition of tissues within the heart as well as various abnormalities. It supplies evidence for the diagnoses of cardiac diseases. For this reason, it has drawn considerable attention in the ECG signal processing field. However, the presence of noise and time-varying morphology makes the detection difficult [20].

QRS detector measures the pulse rate of the patient. It measures one pulse count when the ECG wave crosses the zero axis and comes back from negative to positive axis. The LED will glow as soon as pulse is counted. Fig. 6 and 7 shows the block and complete circuit diagram of QRS detector. The QRS detector circuit consists of the following five units:

- QRS filter
- Half-wave rectifier
- Threshold circuit
- Comparator
- Monostable

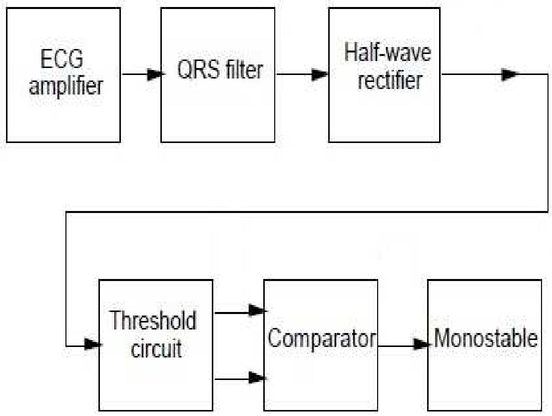

Fig. 6: Block Diagram of QRS Detector

i) QRS Filter

The power spectrum of a normal ECG signal has the greatest signal-to-noise ratio at about 17 Hz. Therefore to detect the QRS complex, the ECG is passed through a band pass filter with a centre frequency of 17 Hz and a bandwidth of 6 Hz. This filter has a large amount of ringing in its output [27].

ii) Half-wave Rectifier

The filtered QRS is half-wave rectified to be subsequently compared with a threshold voltage generated by the detector circuit.

iii) Threshold Circuit

The peak voltage of the rectifier and filtered ECG is stored on a capacitor. A fraction of this voltage (threshold voltage) is compared with the filtered and rectified ECG output.

iv) Comparator

The QRS pulse is detected when the threshold voltage is exceeded. The capacitor recharges to new threshold voltage after every pulse. Hence a new threshold determined from the past history of the signal is generated after every pulse.

v) Mono-stable

A 200-ms pulse is generated for every QRS complex detected. This pulse drives a LED.

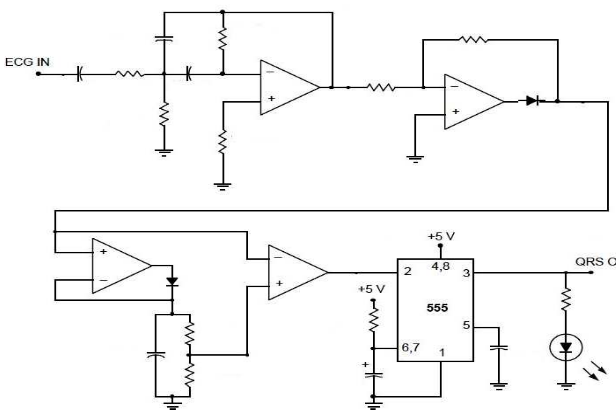

Fig. 7: QRS Detector Circuit

The problem arises in case of patients having cardiac pacemaker. Since sharp pulses of the pacemaker can cause spurious QRS pulse detection, an extra circuit is often included to reject pacemaker pulses. The rejection is achieved by limiting the slew rate of the amplifier.

IV. SOFWARE IMPLEMENTATION

The software is based on two parts design. One, for getting and processing ECG signal which is implemented within the PIC16F876.The other one is a Graphic Unit Interface easy to use by the patient. It is developed by using the Visual Basic [17] language under Windows as operating system.

A. Microcontroller Software

In this case, the method consists of computing a cardiovascular rate of the person each minute. A pre-processing step is needed to perform an amplification of the signal and a hardware filtering to eliminate noise. The QRS pulse has higher energy and a heart pulse can be detected within five to six zero crossing of the signal [28].

The rate counter [2], representing the number of pulses during one minute, is incremented at detection of a QRS pulse. It is then compared with two references representing bradycardia or arrhythmias and tachycardia for adult or children as the case may be. These referenced values were taken by statistical computation. The adult normal heart rate is in the range of 70 and 90 beats [25], while that of an infant is in the range of 100 and 120 beats per minute at rest. If the heart rate counter is different from references then display indicator shows it and an audio signal can be generated. After a minute, the rate count is stored in the external EEPROM, if it is different from the previous count. This is followed by an internal clock time which should be synchronized with real-time clock. Thus, at every sensitive variation of the pulse rate, three bytes would be stored. These bytes represent the rate count, the hour and the minute of the internal clock. As mentioned, a graphic unit interface easy to use by the patient, using Visual Basic language under Windows as operating system has been developed. The main menu of the application provides the user with acquisition, display and transfer.

The micro-controller is interfaced with the PC or laptop by burning the program written in C language for the Micro-controller PIC16F876 [23]. The program thus, displays the input given on the LCD. In this project, we have given the initial default input "H B S", which will be printed onto the LCD. The algorithm [10] shows the process of software coding. When the switch is turned on, LCD is initiated. The variables hflag and lflag are initialized with value 1, and tcount is initialized with value 0. If tcount is less than or equal to 100000 seconds, then lflag is compared with 1. If lflag is equal to 1 then the variables are updated as lflag = 0 and hflag = 1. If lflag is not equal to 1 then the variable lflag will be changed as 1 and hflag will be 0, and the program ends. If the first condition is not satisfied i.e. tcount <= 100000 is false, then the variables are updated as hflag = 1 and lflag = 1, and the program ends. This program thus measures the pulse count on the basis of zero crossing of the ECG wave [30].

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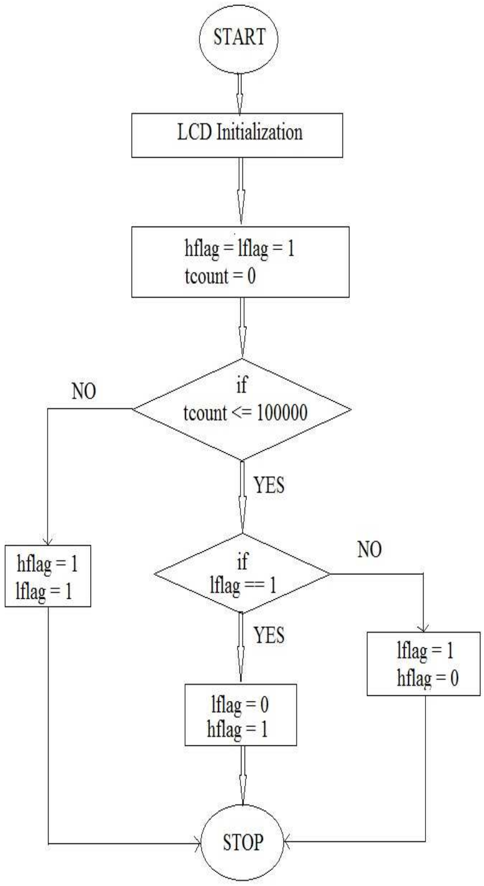

Fig. 8: Flow chart of HBS Software Process

B. PC Software

In the acquisition function, the ICST circuit should be connected to the parallel port of the PC and the process of reading the EEPROM with saving data in a LED is done. On the other hand, the display function shows to the user the contents of the EEPROM in hexadecimal mode. It also draws a graph representing the variations of the ECG signal.

The first area of the design involves the ECG sensor (obtaining data) and construction of an ECG signal for display. The sensor involves analogue circuitry required to obtain an ECG reading (bio-potential) from the patient. The signal obtained here must then be shifted to the correct voltage range for it to interface to an ADC on the Microcontroller. This process is completed by amplification and noise filtering circuitry. The next event checks and detects the Heart Rate and further this data is sent to a PC through the USB. Once the ECG data is sent to the PC, the data is first computed upon and used to plot the ECG signal.

On the software panel, when snapshot button is clicked, the software generates the snapshot of the real time ECG [11] and is saved in the desired place. Finally, on clicking the e-mail option the transfer function activates the Microsoft Outlook to send to the doctor an attached ECG file along with the details like Patient's name, address, age, Patient ID, etc. By using the same application, the doctor can display an ECG file and then can take a better diagnosis concerning the status of the patient. Hence the doctor would receive better information on the evolution of the patient heart rate in advance. Our works shows the techniques for signal processing via software to reduce noise or classify heart pathologies.

Thus, the design will involve sensor electronics, noise filtering, and signal reconstruction. The Parameter Measurement area is mainly responsible for details of the concluded parameters like intervals, amplitudes, etc. Then, these parameters are sent to the doctor's device through e-mail [9]. In case of any emergency, the ambulance can be sent to the patient's address in no time.

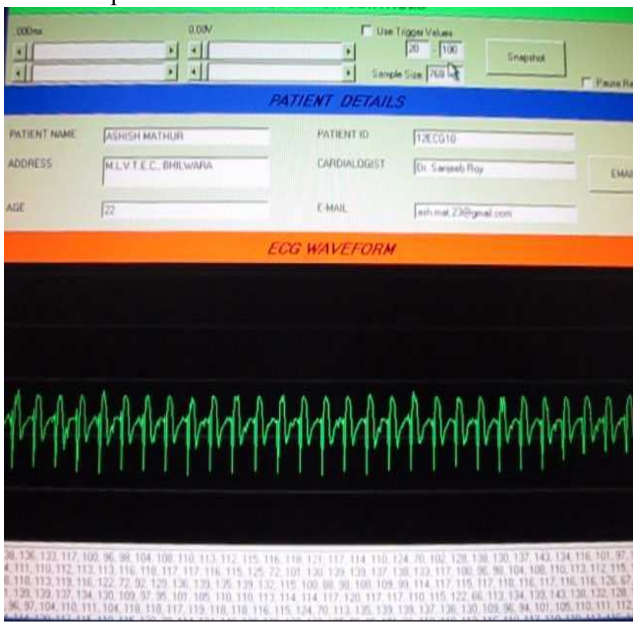

Fig. 9: PC Software view of HBS

The software panel consists of following properties:

1. Cardiologist's e-mail address, so that patient can easily send his mail.
2. The e-mail consists of ECG wave snapshot and patient's detail like his name, address, age etc.
3. The ECG wave is real time on the software platform.
4. The waveform also shows the amplitude and time intervals.

V. RESULTS

We have successfully designed an efficient integrated wireless ECG monitoring system. The device which can get ECG signals from human body and send the ECG data in digital form to a PC as well as doctor's device. In addition, the network application successfully sets up a full duplex and point-to-point connection. The networking system enables transfer of ECG, heart pulse rate and other parameters and also retrieves, update and create patient's medical record database for the doctor to work on. A possible application of this tool is to receive ECG data in the hospital from an emergency unit. Thus, the objective for this project, which is real time monitoring of Electrocardiogram (ECG), is achieved.

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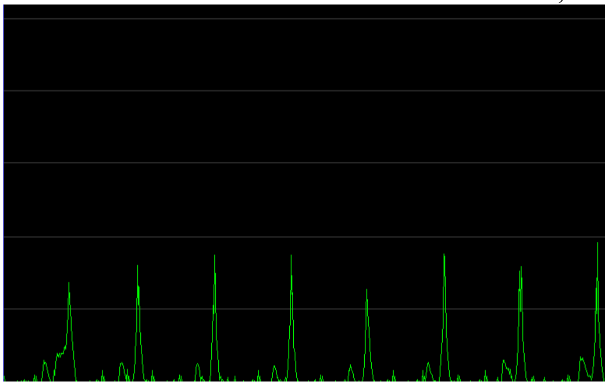
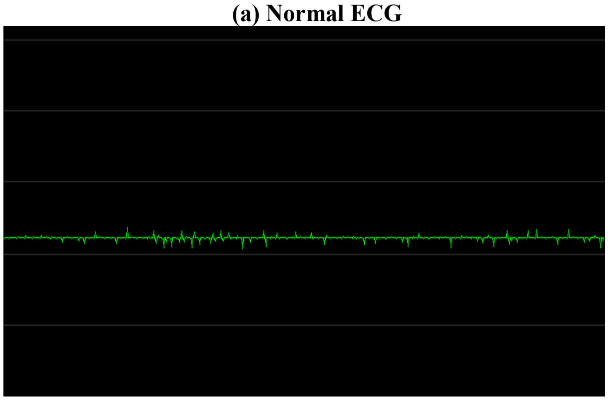
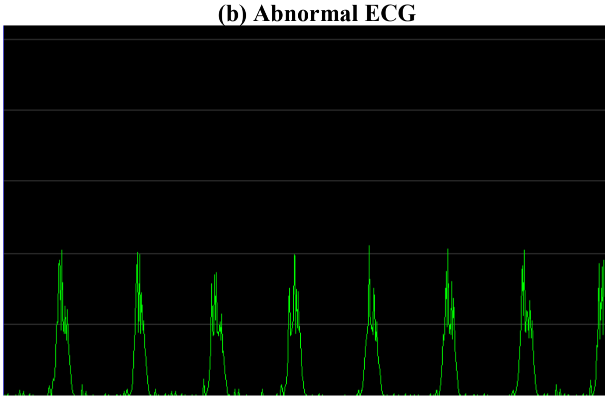


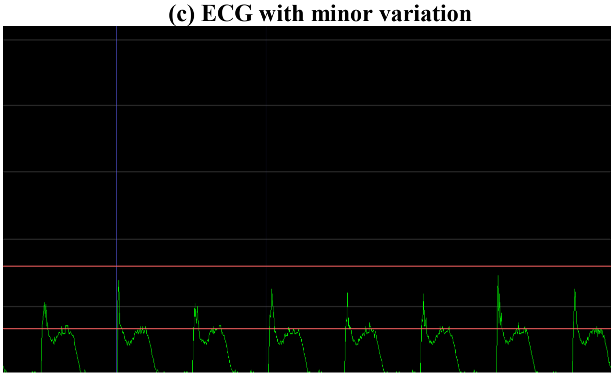
(a) Normal ECG



(b) Abnormal ECG



(c) ECG with minor variation



(d) ECG with major variation

Fig. 10 Different type of ECG waves on the HBS software panel

In figure 10 (a), a normal ECG wave is shown which interprets that the person is normal without any kind of heart disorder. Figure 10 (b) shows an abnormal ECG wave which is extremely dangerous and can be fatal for the patient. This type of condition arises due to improper flow of blood in arteries and veins, etc. This is not at all required. The figure 10 (c) shows variation in normal ECG wave which can be interpreted as minor attacks and change in pulse count and figure 10 (d) shows major variations in ECG which are seen as major attacks. In this case patient needs to be in doctor's care.

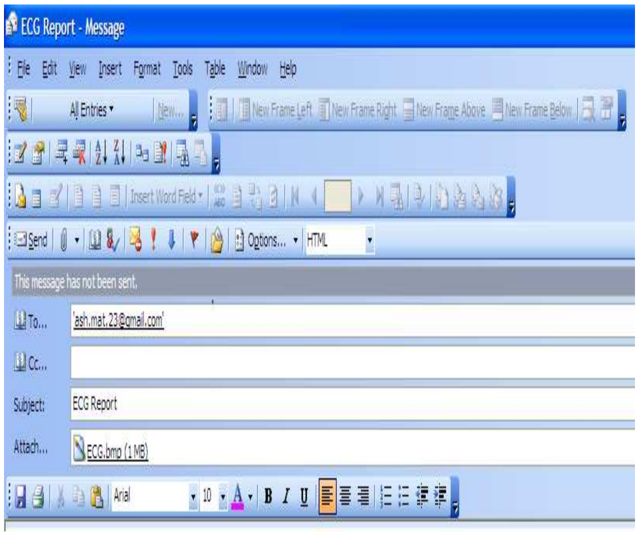


Fig. 11. Microsoft Outlook panel in the HBS

Figure 11 shows the Microsoft outlook interface used in HBS for the purpose of sending e-mail to the concerned cardiologist. The ECG wave snapshot is attached along with all the details of patient.

The ease of the device can be seen as the person only requires mounting electrodes onto the body and switching ON the device. The pulse rate shown is very useful for the patient, as understanding of ECG is very tedious job. So, on the basis of pulse rate, the patient can judge whether or not, the report is to be sent to the doctor.

VI. CONCLUSION

We have designed a low cost ECG device having emergency response which is easy to install and work on for a patient with little of previous knowledge. The design is kept easy so that it can be upgraded anytime as the technology grows. Technologies used are latest and perfect for the cause. The development of software tools both for a computer and for mobile device enables a large range of application scenarios. The main advantage of the proposed system is decreasing the intervention time to the patient in an emergency situation. Consequently, proposed low-cost system can increase the quality and ease of life of patients.

Future research includes other signal processing techniques and hardware processing of the ECG signal for automatic detection in pathologies. The one approach can be by using mobile device instead of PC or Laptop. The alarming feature and further automation of the system can also prove to be fruitful.

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ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
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